THE USE OF HOUSEHOLD FILTERS FOR POTABLE WATERS.

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During the past two years I have instituted repeated investigations as to the value of the portable filters, in very common use for the filtration of rain-water in Ann Arbor, where filtered rain-water is used for drinking and culinary purposes by probably more than half the families. There are various patterns of these filters in use, but in all cases the filtering material is coarsely powdered wood charcoal, usually with intermixture of gravel, and the mechanical support of layers of gravel. The water is strained by passing through a sponge, and then filters through a bed of charcoal-gravel, from 12 to 20 inches in depth. The filtering material is close enough so that, with a horizontal area of 12 to 20 inches diameter, the water does not pass out faster than in a barely continuous stream.

Most of the waters upon which the filters were tried were the rain-water from different cisterns at private houses, the same water drawn upon to be filtered for potable uses. In the greater number of cases these representative samples of rain-water were found to contain too much organic matter to be perfectly wholesome, as the results show, but they were not very bad. Then there were two samples of rain-water, tried in filtration, that were decidedly bad, so that they must have been contaminated by foul cisterns, or foul gutters, or in some way. And, to see what filtration would do in case of extremely bad waters, four samples were made impure by addition of urine. One sample of well-water (found not very good), and one of spring-water (found fairly good), were also taken, for trial of the filters.

The determinations were made by a chemical analysis of the water before filtration, and exactly the same chemical analysis after filtration. The impurity chiefly considered was that of organic matter, or, more definitely, the most putrescible organic matter, that of nitrogenous composition. This was determined by Wanklyn's process, as "albuminoid ammonia," and "free ammonia."*

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* Wanklyn's method continues to be sustained as a useful practical measure of the wholesomeness of water. It does not represent the whole of the nitrogen of all organic substances; but for any given substances, it is an accurate index of their increase or diminution, and for comparison of the same water, before and after filtration, it is an admirable method. As to Frankland's method for the determination of nitrogen and carbon, it seems to be impossible to know how much dissociation of putrefactive matter will occur in the evaporation to dryness, even with the precautions taken. The trial here made of Tidy's new "oxygen process," mentioned in this report, did not at all satisfy us of its value.

In ten of the comparative trials, the total residue at 212° F., the residue after ignition, with resulting loss by ignition, and the proportion of chlorides, were also determined. Tidy's "oxygen method" of determining organic matter was also tried, in comparison with Wanklyn's "ammonia-process," upon five samples of water, both before and after filtration. In all, twenty-seven different samples of water were subjected to analysis, each before and after filtration.[*]

It may be now stated, in advance of the tabulated details and of explanations, that the investigation sustains the following *practical conclusions:*

First. A good portable charcoal filter, such as described, when in good order, removes from eighty to ninety per cent of the putrescible organic matter, from rain-water.

Second. Such a filter, in good order, supplied with unpolluted rain-water, collected and stored with due cleanliness, and with strictest exclusion of ground drainage, furnishes a very pure water (containing an average of only three-tenths and at most seven-tenths of the maximum safe quantity of nitrogenous organic matter.)

Third. A good filter, in good order, cannot be at all depended upon to make polluted water safe for drinking. (Any water containing the free ammonia found in filtered waters Nos. 5 to 10, especially with the albuminoid ammonia of Nos. 5 and 6, would be rejected by a chemist as unsafe.) A polluted water, probably containing animal excreta, is liable to carry specific poison, as that of typhoid, and no filtration can be at all trusted to make it safe.

Fourth. In case of any potable water not decidedly bad and yet containing such traces of organic matter as to make its use of doubtful safety, the danger from its use is very greatly lessened by its filtration through a good filter, in good order.

Fifth. A good charcoal filter, used for clean rain-water, and *not kept submerged* over half or two-thirds of the time, but left with the filter-bed drained off a part of every day, will remain in good order for considerable time, and may be relied upon for at least a year. Air is far better than the purest water to cleanse a good charcoal filter. The better the filter, the more readily is it cleansed of organic matter by atmospheric oxidation. Due care of a filter requires that all suspended matters should be removed before the water reaches the filter-bed. This is well accomplished by the sponge interposed between the reservoir of unfiltered water and the bed. Of course water that is loaded with impurities (especially dissolved impurities) will far sooner clog a filter-bed and make it worthless. It is only when supplied with approximately pure water that the slight organic residues can be removed by atmospheric oxidation, and the filter be considered an almost permanent means of purification.

Sixth. Water should not be stored after it is filtered. Filtered water is like the manna of the Hebrews; it must be obtained fresh every day. Organic growths, algæ, multiply in even pure water. These bodies are highly nitrogenous; perhaps taking nitrogen from the air; and they should be removed. Filtration does it.

FILTRATION includes three distinct operations:

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[*] These analyses were executed, under the writer's direction, by Messrs. E. M. Reed, Theo. Hauck, A. H. Vandivert, and B. F. Dawson,—all then students of the School of Pharmacy of the University of Michigan, and all now graduates of the same. Messrs. Reed and Hauck made the first ten double analyses, with determinations of residues before and after ignition, and of chlorides. Their results are reported in the Chemical News, London, xxxvii., 107 (March 15, 1878); also, in part, in Michigan Medical News, Aug. 10, 1878. The last fifteen double analyses, with trial of Tidy's process upon five of the same, were done by Messrs. Vandivert and Dawson, in 1879, and not hitherto published. I wish to testify to the fidelity of each of these analysts. In the ammonia-process, the most rigid precautions were used to exclude atmospheric ammonia. Distilled water was made ammonia free, and blank determinations carried to insure freedom from interference.

First,—Straining. The mechanical removal of solid particles, suspended in the water. It is these that, when abundant enough, render water turbid, or cloudy, and that are deposited by standing in perfect quiet, as in the sedimentation of waters for cities. Filtration upward is sometimes adopted, to obtain sedimentation in the filter without clogging the filter-bed. But a finely porous septum, such as sponge, effectually removes all solid particles. In the use of rain-water, it is a great advantage if at least some degree of straining, the closer the better, can be effected before the water enters the cistern. By straining is usually meant the removal of solid particles large enough to make some degree of cloudiness,—particles large enough to be seen by the unaided eye or with a hand magnifyer. Microscopic particles are not removed by ordinary straining; though they are, in greater part, by a good filter.

Second,—Adhesion. The retention of dissolved matters in the filter-bed. A solution of organic coloring matters, though so perfectly free from suspended solids as to show no particles under a microscope, when passed through certain porous substances, leaves the coloring matter behind. The capillary attraction of the porous surfaces for the dissolved solids takes them out of solution. Dissolved gases are to some extent withdrawn from solution in the same way. The more minutely porous a filter-bed is, the more efficiently it removes organic matter from water. The best filter-bed for this purpose is bone charcoal, perhaps the next best is wood charcoal. But whatever the material, it should be so disposed that the water must all be subjected to capillary attraction, as long as possible, in going through the bed. If there are interstices, so as to permit currents of water, just so much of the water fails to be filtered. And the retention of dissolved solids depends upon finer pores than are needed to take out suspended particles. A good filter-bed must be fine and close enough, so that at any given point the liquid does not pass through faster than by drops; and if, in a section of the bed, of two inches diameter, the water does not pass faster than five to twenty drops in a minute, so much the better. Filters of bone charcoal, in large fragments, put in a box which is sunk in water and from which water is drawn out, have been tried for public water supplies, and have been found to remove far less organic matter than we find these wood charcoal and gravel filters to do. Of course the close filter-bed works too slowly for ready adaptation to public water. The filter-beds used in these experiments are stated to contain about one volume of gravel to three volumes of charcoal. But the result is governed largely by the degree of fineness and compactness. The structure of the bed must be even, so that no channels can be made, and then the rate of flow is the criterion of suitable fineness and compactness. A bed of sand, it has been found, does but little more than remove suspended matters, including organic growths too fine and too light to be removed by sedimentation. The sand particles are not porous, and their surfaces have weak adhesive attraction.

Third,—Oxidation. It has been stated, for some years past, that the organic matters withdrawn from water by a filter-bed are to a degree oxidized away by the air, so that the filter-bed does not clog up. The analyses here submitted, showing the efficiency of filter-beds long in use, prove that a great deal of oxidation of organic matter must have occurred. Otherwise, as is often assumed, the filter-beds would soon get saturated with the organic matter, and then do as much or more harm than good. For No. 1, the filter, which was small, had been in use, for two or three pails of water each day, for eight months; for No. 2, the filter had been longer in use; Numbers 13 to 19, inclusive, were filters which had been some time in use in families, and No.

25 *b* had been in use two years. Yet the efficiency of these filters was found not very much lower than that of the new filters used for Nos. 3, 5, 10, and 11. The filters which had been in use and kept filled and covered with water constantly, did the poorest work, viz., Nos. 4, 12, and 20; notably No. 4, though it had been in use only four months. Also, No. 24 *b*, a charcoal cistern filter, long submerged, only removed twenty-seven per cent of the matter indexed as albuminoid ammonia. Filter-beds need the air to be let through them every day for due exercise of atmospheric oxidation. And it is by this, here named as the third function of filtration, that household filters with charcoal beds become practically useful in purifying water.*

The results of the analyses may be tabulated as below:

	The Filter.	The Water
No.	1, of 8 mos. service, *aired daily*	Cistern rain-water.
"	2, of long " " "	Well-water.
"	3, new	Spring-water.
"	4, of 2 mos. service, *submerged*	Barrel rain-water.
"	5, new	Rain-water, with urine.
"	6, "	" " " "
"	7, "	" " " "
"	8, "	" " " "
"	9, "	" " " "
"	10, "	" " " "
"	11, "	Cistern rain-water.
"	12, in household use, *submerged*	" " "
"	13, " " " *aired*	" " "
"	14, " " " "	" " "
"	15, " " " "	" " "
"	16, " " " "	" " "
"	17, " " " "	" " "
"	18, " " " "	" " "
"	19, " " " "	" " "
"	20, " " " *submerged*	" " "
"	21, " " " *aired*	" " "
"	22, " " " "	" " "
"	23, " " " "	" " "
"	24*a*, one foot of gravel	Rain-water.
"	24*b*, a charcoal cistern filter, *submerged*	Filtrate of 24*a*.
"	25*a*, a brick wall in cistern	Cistern rain-water.
"	25*b*, of 2 years use, *aired*	Filtrate of 25*a*.

"ALBUMINOID AMMONIA," REPRESENTING PUTRESCIBLE MATTER.

Number of parts in one million parts of water.

Less than 0.05, indicates very pure water.
Over 0.10, the water is to be suspected.
Over 0.15, the water is to be condemned absolutely.

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* Oxidation in the filter-bed illustrates a common and important fact in nature. The oxygen, condensed by adhesion in the pores, is extra active. Spongy platinum causes a stream of hydrogen to take fire in the air. Freshly ignited charcoal causes hydrosulphuric acid gas to take fire in oxygen. Dry earth, as used for the closet, Col. Waring says, when exposed months to the air, can be used to take up fæcal matter repeatedly, without gaining in proportion of organic matter, as verified by analysis. Purification by atmospheric oxidation, is nature's great means of cleansing rivers; in this case being done in a swift running current; and very rapidly in water spray.

Waters.	Before Filtering.	After Filtering.	Removed by Filtering.
No. 1	0.30	0.01	96 per cent.
" 2	0.14	0.06	57 " "
" 3	0.07	0.07	0 " "
" 4	1.14	0.57	50 " "
" 5	1.90	0.10	94 " "
" 6	0.40	0.10	75 " "
" 7	0.50	0.03	94 " "
" 8	0.38	0.06	84 " "
" 9	0.30	0.04	86 " "
" 10	0.06	0.01	83 " "
Average of first ten	-----	-----	72 " "
No. 11	0.204	0.015	92 " "
" 12	0.184	0.034	82 " "
" 13	0.090	0.009	90 " "
" 14	0.365	0.069	81 " "
" 15	0.216	0.036	83 " "
" 16	⎫	0.025	88 " "
" 17	Av.	0.031	85 " "
" 18	of ⎬	0.032	85 " "
" 19	five,	0.028	87 " "
" 20	⎭ 0.212	0.037	83 " "
Average of second ten	-----	0.032	86 " "
No. 21	0.180	0.032	82 " "
" 22	0.270	0.010	93 " "
" 23	0.300	0.040	87 " "
Average of three	0.250	0.027	87 " "
No. 24a	0.230	0.110	52 " "
" 24b	0.110	0.080	27 " "
" 25a	0.250	0.230	10 " "
" 25b	0.230	0.070	66 " "

As "albuminoid ammonia" is the best of the measures of putrescible organic matter, it is interesting to see in what instances it was found as high as the danger-limit of 0.10 part per million, in *filtered* waters. These are the only instances, out of the twenty-seven experiments:

No. 4, water fearfully contaminated in some way, probably by accumulations in a water-barrel, with a filter kept constantly water-logged.

No. 5, polluted rain-water, nearly purified of putrescible matter, by a new filter, but still loaded with products resulting from previous putrefaction, as seen by the enormous "free ammonia", in next table.

No. 6, like No. 5.

No. 24a. Leached through a layer of gravel only.

No. 25a. Filtered through a two-inch brick wall.

"FREE AMMONIA," A SECONDARY RESULT OF ORGANIC MATTER.

Number of parts in one million parts of water.

Over 0.08 is an indication of questionable purity, and in case of well-water, points to cess-pool or sewage contamination.

Waters.	Before Filtering.	After Filtering.	Removed by Filtering.
No. 1	0.50	0.070	0.430 or 86 per cent.
" 2	0.08	0.020	0.060 " 75 " "
" 3	0.05	0.008	0.042 " 84 " "
" 4	1.34	0.140	1.200 " 89 " "
" 5	33.00	8.100	24.900 " 75 " "
" 6	4.00	0.400	3.600 " 90 " "
" 7	2.50	0.080	2.420 " 96 " "
" 8	4.06	0.620	3.440 " 84 " "
" 9	1.94	0.420	1.520 " 78 " "
" 10	1.08	0.180	0.900 " 83 " "
Average of first ten numbers	----	-----	84 " "
No. 11	1.211	0.084	----- 93 " "
" 12	1.123	0.246	----- 78 " "
" 13	0.943	0.114	----- 88 " "
" 14	1.145	0.172	----- 85 " "
" 15	1.342	0.082	----- 94 " "
" 16	} Av. of five, 1.153 {	0.093	----- 92 " "
" 17		0.132	----- 88 " "
" 18		0.219	----- 81 " "
" 19		0.081	----- 93 " "
" 20		0.252	----- 79 " "
Average of second ten Nos.	-----	0.155	----- 87 " "
No. 21	0.560	0.120	----- 79 " "
" 22	0.530	0.090	----- 83 " "
" 23	0.570	0.130	----- 77 " "
Average of three	0.553	0.113	----- 80 " "
No. 24a	0.540	0.270	----- 50 " "
" 24b	0.270	0.190	----- 29 " "
" 25a	0.510	0.460	----- 9 " "
" 25b	0.460	0.095	----- 79 " "

These results indicate that charcoal filtration removes ammonia, and the crystalloid substance, urea, as efficiently as it removes the colloid bodies indexed as "albuminoid ammonia." In the distillation with addition of potassium hydrate, urea is chiefly converted into ammonia; while it is not obtained as "albuminoid ammonia", by the action of permanganate, in Wanklyn's process. The polluted waters, Nos. 4 to 10, show a large percentage of removal of "free ammonia", although filtration does not purify them to an extent at all warranting their use. No. 5, loaded with urine, and showing the conversion of urea into "free ammonia" by the enormous proportion of 33.00 parts per million, so overpowered the cleansing power of a new filter as to leave 8.100 parts of "free ammonia" per million parts of water, after filtration.

The proportion of "free ammonia" in the filtered rain-waters is in general so large as to suggest that ammonia may result from atmospheric oxidation of organic matter in the filter-bed. I have had in view some determinations for nitric acid as a result of such oxidation, but have as yet obtained no results suitable for report. The submerged filter-beds, Nos. 4, 12, and 20, removed "free ammonia" to a fair extent,—though less than an average in case of the last two named.

Of the good filters, in good order (or having air let into the filter-beds), Nos.

13, 14, 17, 18, 21, and 23, fail to remove the "free ammonia" as fully as they ought to do, all these leaving over 0.09 parts per million. But as these all give, of "albuminoid ammonia", the chief test of purity, less than 0.07 parts (all but one, less than 0.05 parts), the filtered waters may perhaps be accepted as safe.

Some analyses of various waters at home and abroad may be here presented for comparisons:

	Parts per Million.	
	Free Ammonia.	Albuminoid Ammonia.
Town water, Manchester, England	0.01	0.07
" " Glasgow, Scotland	0.00	0.08
" " Chelmsford, England	0.08	0.02
" " London, Lambeth Co.	0.01	0.16
Thames river, London Bridge, at two hours' flood	1.76	0.35
Thames, above Hampton Court*	0.04	0.28
Springfield, Mass., Town water†	0.09	0.28
The same, sand-filtered	0.07	0.23
Poughkeepsie, N. Y., river water	0.11	0.20
The same, sand-filtered	0.08	0.14

The *absolute quantities* of impurities may be more readily compared with various standards, if I give the *equivalent of "parts per million"*, for some of the results, *in "Grains per Gallon", as follows:*

	"Albuminoid Ammonia."	
	Before Filtering.	After Filtering
Average of Nos. 11 to 15	0.012363	0.001924
" " Nos. 11 to 20	--------	0.001866
" " Nos. 21 to 23	0.014579	0.001592
" " Nos. 11 to 15	0.067240	0.008164
" " Nos. 11 to 20	--------	0.008631
" " Nos. 21 to 23	0.03224	0.006607

The results obtained in Total Residue, and Residue after Ignition, are here given, as being data commonly furnished. They are of no real value regarding organic matter,—as the loss by ignition is due to many things beside destruction of organic matter. The Residue after Ignition, as lessened by filtration, is of more interest regarding any effect of filtering upon the *mineral constituents*.

Grains of Residue left from one Gallon of Water.

	AT 100° C.			AFTER IGNITION.			Difference by Ignition.
	Before Filtering.	After Filtering.	Difference, Per Ct.	Before Filtering.	After Filtering.	Difference, Per Ct.	
No. 1	24.556	11.265	54	10.526	10.101	4	12.866, or 91 per ct. less.
" 2	119.274	102.343	14	87.362	85.141	2	14.710, or 46 per ct. less.
" 3	82.432	81.876	0.6	33.322	31.926	4	0.840, or 2 per ct. more.
" 4	35.084	30.243	13	3.508	2.836	19	4.169, or 13 per ct. less.
" 5	222.723	197.226	11	106.997	76.385	29	5.115, or 4 per ct. more.
" 6	199.952	156.107	21	73.662	70.263	4	40.446, or 32 per ct. less.
" 7	197.693	141.826	28	86.915	83.715	6	52.677, or 47 per ct. less.
" 8	181.273	150.194	17	63.781	59.624	3	26.922, or 23 per ct. less.
" 9	110.963	97.852	12	64.876	41.973	35	9.828, or 21 per ct. more.
" 10	102.837	89.651	13	71.139	55.851	21	2.102, or 6 per ct. more.
Mean	--------	--------	18	--------	--------	13	13.390, or 22 per ct. more.

* This and the previous five water analyses, from Wanklyn's Water Analysis.
† This and the following four water analyses, from Prof. Wm. Ripley Nichols, Mass. State Board of Health, Ninth Yearly Report.

As a matter of course any removal or addition of mineral constituents of water, in filtration, must cease after a time, in continued use of a filter not changed. If some salts are deposited, the filter will become saturated with these salts; if some salts are imparted, the filter will become exhausted of these. In general, a charcoal-gravel filter will not affect the mineral constituents in a notable degree, or to have any practical influence upon the value of the water. It is a matter of some doubt, I believe, whether "soft water", destitute of earthy salts, is as wholesome a drink as water with some "hardness." I am myself inclined to believe (though desiring more evidence), that earthy bases are sufficiently supplied by our solid food, and need not be taken in our drink. It is true, no doubt, that many of us, especially during growth and dentition, suffer from lack of phosphates. But I think it the acid, not the base of phosphates, that is deficient, and we do not look to any water for phosphoric acid. If it is desirable to add any mineral constituents to drinking-water, this could easily be done by an occasional addition to the filter-bed.

As to the importance of the drinking-water, the present writer has no need to make a plea. The well in the door-yard does not always furnish the wholesome beverage, that has been its traditional reputation. The danger of underground drainage is now well demonstrated. Not only liquids but gases, and poisonous gases circulate through the soil, as has been proved by Pettenkofer. the German scientist, in a startling array of facts, presented a few years back, The yearly reports of the Michigan State Board of Health prove it. Fearful destruction in families, and devastating typhoid endemics in various quarters have attested it. The insufficiency of the soil to purify all the water that comes from it, and to cut off all the currents of filth that go into it, has been demonstrated by experiments given at this meeting by a colleague, whose work I know to be admirably done. It has been the householder's practice in Scotland, said Prof. MacAdam, a few years ago, after building his house, to dig two holes in the door-yard, one for a well and one for a cess-pool. So it has been in America. Not only the well, but even the cistern, by overflow-pipes and leakages, has been contaminated by drainage. That some resource for wholesome water may always be at command, in the present prudent distrust of previous water-supplies, the writer offers these results as to household filtered waters.